



# Remote Sensing Applications in Thua Thien - Hue Province

**Tran Dinh Lan** (*IMER- Institute of Marine Environment and Resources, Haiphong, Vietnam*)

**Tom Bucx** (*Deltares, Delft, the Netherlands*)

**Robbert Misdorp**

## Contents

1. Coastal challenges in TT Hue Province at the end of the 1990's
2. Benefits of Remote Sensing applications
3. Objectives of CCP task5
4. Organisation
5. Results of cooperative efforts for the TT Hue Province
  - 5.1. Updated thematic maps
  - 5.2. November 1999 flooding
  - 5.3. Changes in land cover/land-use
  - 5.4. Estimates of soil erosion related to land-use changes
  - 5.5. Detected changes in shorelines related to coastal hydraulic conditions
  - 5.6. Changes in aquaculture development
  - 5.7. Meta-database of RS-imageries
  - 5.8. Remote Sensing information as input for Integrated coastal modelling
  - 5.9. Two two-week intensive RS training courses
6. Conclusions & recommendations
7. References, PDF reports and Websites

## Summary:

Remote Sensing (RS) combined with Geographic Information Systems (GIS) is a powerful tool for coastal policy and decision makers.

Recognising the value of these tools at a national level, efforts were made to introduce these applications at a provincial level through two intensive training courses in Hue, capital of the Thua Thien – Hue (TT Hue) Province. Provincial trainees demonstrated the value of the various applications to the high-level provincial authorities. Remote sensing interactions between the international, national and provincial experts were shown to be useful for ICZM planning and implementation in the Thua Thien - Hue Province.

## **1. Coastal challenges in Thua Thien - Hue Province at the end of the 1990s**

In Thua Thien - Hue Province, the economic development and population growth results in increasing demand for natural resources and a potential overload of the carrying capacity of the natural coastal systems. Depletion of natural resources and pollution of land and water also occur. Moreover, cyclones and related flooding are expected to occur more frequently in the near future due to the anticipated impacts of climate change. These impacts will exacerbate the current problems. Earlier studies of the (environmental) situation in TT Hue Province revealed that there are several areas of conflict between uses and there is a strong need for an improved management system to support decision-making balancing the different competing interests and creating sustainable land use policies. The introduction of the ICZM concept in the provincial planning and decision making process is addressing these issues. ICZM is being introduced at both national level and at provincial level, implementing a range of governmental projects in TT Hue. A number of ICZM projects were supported by the Netherlands CZM-C/Ministry of Transport Public Works and Water Management (Min.V&W) and Ministry of Foreign Affairs (described in detail in CCC II-8-1).

## **2. Benefits of Remote Sensing (RS) applications**

In TT Hue Province, it has been recognised that remote sensing can support:

- Cross checking, correcting and improving data and GIS maps helping the establishment of an ICZM meta database and GIS tools;
- The creation of land and water-use maps, mapping vulnerable and remote areas and drafting a Zoning Plan,
- Environmental and coastal monitoring, especially synoptic overviews, rapid assessments of changes and flood mapping, which are saving time and money by obviating the need for laborious monitoring fieldwork over a large area. Limited, but important ground truth surveys of selected areas are however always needed.

Moreover, other projects in TT Hue can also benefit from Remote Sensing: Forestry programmes (Department of Agriculture and Rural Development) and the Natural Disaster Mitigation initiative.

Although many relevant coastal scientists and policymakers recognised the benefits of remote sensing applications, they were also aware that there was only limited knowledge in their province. Therefore, the challenge was to introduce RS and its applications to the TT Hue Province.

## **3. Objectives of CCP task5 on Remote Sensing**

The Vietnam-Netherlands Coastal Cooperative Programme (CCP) Task5 on Remote Sensing and GIS Applications aimed to:

1. To introduce the technology (available at Vietnam national level) to the TT Hue provincial level;
2. To increase the understanding of dynamic processes affecting the coastal zone of the province.

Specific focus was on the supporting role of RS in aquaculture development, changes in land use and effects on soil erosion, and the design of maps of flood prone areas.

To increase capabilities at provincial level is also recognised in the Vietnam National Remote Sensing Master Plan 2010. Training courses for officials and the development of primary RS facilities and human resources are essential elements.

## **4. Organisation**

To implement this task, a CCP RS Task Group 5 was formed with the participation of the professional remote sensing institutions of Vietnam and the Netherlands.

The main Vietnamese Remote Sensing centres involved were: Institute of Marine Environment and Resources (former name: Hai Phong Institute of Oceanology), and the Hanoi based institutes: the General Department of Land Administration (GDLA) and the Institute of Geography/Vietnam Academy of Science and Technology and CEDIM/FIPI (Centre for Data Information and Mapping). Each Remote Sensing Centre has its own capabilities and capacities to produce valuable RS applications.

The Netherlands based ITC (International Institute for Geo-information Science and Earth Observation, see website), WL-Delft Hydraulics (=Deltares, see website), IVM (Free University, Amsterdam) and CZM-Centre/Min. V&W provided expertise and training assistance.

The first CCP Workshop on: "Remote Sensing applications for ICZM in TT Hue Province" was held in Hanoi, September 2002. During this introductory workshop, the work plan of CCP Task5 was shared and discussed among the 55 participants.

Two capacity building training workshops held in Hue city, each two weeks and with 40 - 50 participants. These two training courses facilitated the transfer of knowledge from the Netherlands and Vietnamese Remote Sensing Institutes to the TT Hue Province. This involved the processing and analysing of images (1992, 1999/2000) of TT Hue Province involving several different RS and GIS fields of activities. The RS and GIS results of these hands-on training workshop were put together with ground-truth monitoring results in a integrated lagoon mathematical model directed at the carrying capacity of the Tam Giang lagoon system (see also CCC II-8-4).

## **5. Results of Remote Sensing cooperative efforts for the TT Hue Province**

The CCP Task 5 activities were directed to increase concrete coastal geo-information delivered by RS & GIS analyses to support the high level provincial authorities (Misdorp et al 2005). These products included a variety of thematic maps on topography and land use, and sequential and spatial RS analyses used for the detection of:

- o Changes in land cover and development of soil erosion maps;
- o Shoreline changes;
- o Rapid aquaculture development;
- o Impacts of the November 1999 flooding.

The RS and GIS activities undertaken by the involved Vietnamese and Netherlands RS Centres and Institutes resulted in the following products.

### **5.1 Updated thematic maps of the TT Hue Province**

The Remote Sensing Centre of General Department of Land Administration (GDLA) has created the following set of digital maps at 1:100,000 scale using different kind of satellite imagery such as SPOT, Landsat ETM, Radarsat and other data sources:

- General geographic / topographic map;
- Land use, urbanisation and infrastructure map;
- Ecology and environmental sensitivity map;
- Flooding map.

The updated mapping, using remote sensing, shows the advantage of remote sensing data and technique in thematic map production. Updates of the maps were produced and stored at the Remote Sensing Centre of the General Department of Land Administration.

### **5.2 Composite RS image of the November 1999 wide spread flooding caused by a fierce cyclone**

Tropical Storm 'Eve' brought torrential rains to Central Vietnam. The storm made landfall 110km southeast of Da Nang on October 19. It was the first in a series of storms bringing torrential rain to Central Vietnam, which experienced the heaviest cyclone and rainfall to hit the region for 40 years. The floods killed 793 people, made over 55,000 homeless and more than 5,000 ha of rice paddies were damaged. The floods also caused nearly \$300 million of damage directly to infrastructure, agriculture and aquaculture (ADPC, 2003). Heavy downpours of rain followed and during the first four days of November this amounted to 2700 mm rainfall in Hue city (Figure 1), which is 3.5 times the annual rainfall in Holland. This caused very severe flooding of the coastal plain and the lagoon.

Impacts of cyclones and flooding can be monitored by satellite images. Analysis of a series of Radar-Sat images acquired during the flooding event in first two weeks of November 1999 shows the very large extension of the flooded area and the slow retreat of water during the following days. A composite remote sensing image was made and shows the flooded area by projecting the 6<sup>th</sup> of November Radarsat flooding image on top of 'normal' Landsat image of the 1<sup>st</sup> September 1999.

The purple shaded area in Figure 2 represents the flooded area: the deeper the purple hue, the larger the water depth on top of the ground level. The water depth during maximum flooding was about 5m. in the dark purple flooded area around the mouth of the main river, the Perfume River debouching in the Tam Giang – Cau Hai lagoon.

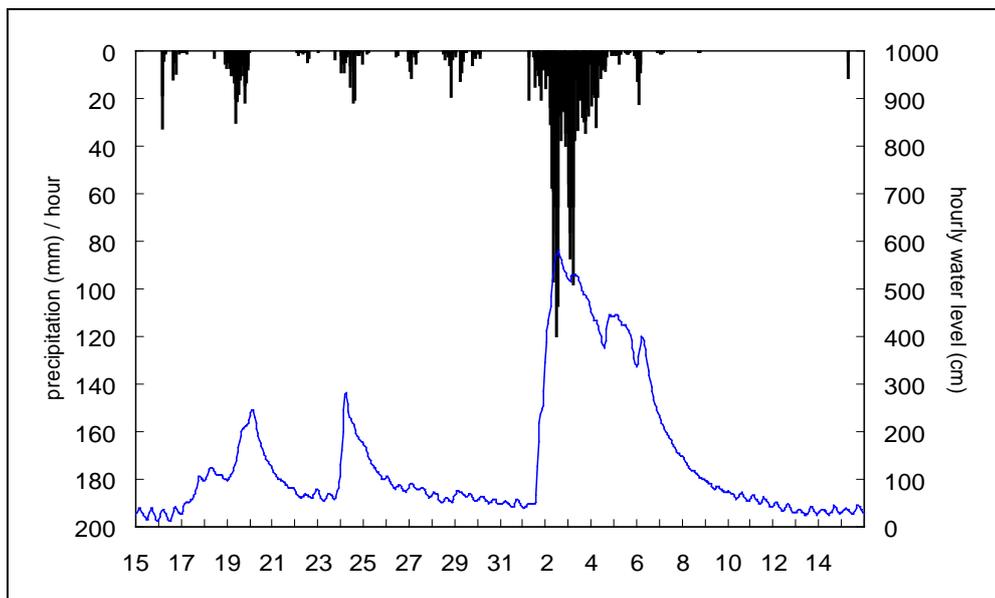


Figure 1:  
**Hourly precipitation at the Meteorological Station of Hue and river water level response of the Perfume River at the Hydrological Station of Kim Long (in Hue city) from October 15 – November 15, 1999;**  
*The river water levels in centimetres above National Datum (N.D.);*

*The intense rainfall on the 2, 3 and 4 th November 1999 caused strong rise in water level (6m) in a few hours time and extensively flooded the areas surrounding the TT Hue Tam Giang - Cau Hai Lagoon. (source: Meteorological Station Hue, CCP- 2002).*



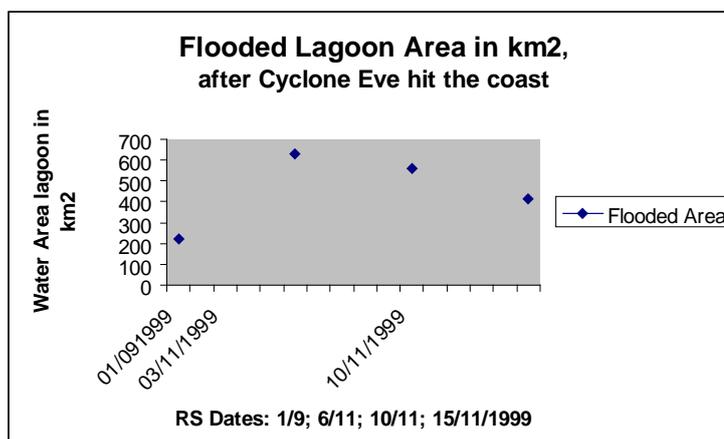
Figure 2: **Composite image of Landsat 1/9/1999 and Radarsat 6/11/1999** to identify flooded areas(purple shaded) surrounding the Tam Giang- Cau Hai lagoon in TT Hue Province; the deeper the purple hue to larger the water depth on top of the ground level. (source: © IMER / Ministry of Agriculture and Rural Development)

The deluge of the flood, both extent and water depth, was very large and was even larger during the very first days of November compared with the 6<sup>th</sup> November situation. The extensive area flooded reached more than three times the area of the Tam Giang – Cau Hai lagoon under normal weather conditions, as depicted in the 1<sup>st</sup> September 1999 image

Sequential analyses of remote sensing images of the lagoon before, during and for some weeks after the cyclone had hit the coast and heavy rain battered the mountains and coastal zone of TT Hue revealed:

1. The Lagoon area was very severely flooded. Four days after the deluge started the flooded area was about three times larger than the reference water area of the lagoon, which is about 225 km<sup>2</sup> (date 1/9/1999);
2. The receding water of the flood is a slow process: after two weeks the flooded area is still about twice as large as the reference, the 'normal' water area. Notably the low-lying shore areas of the lagoon were then still to a large extent flooded (Figure 3).

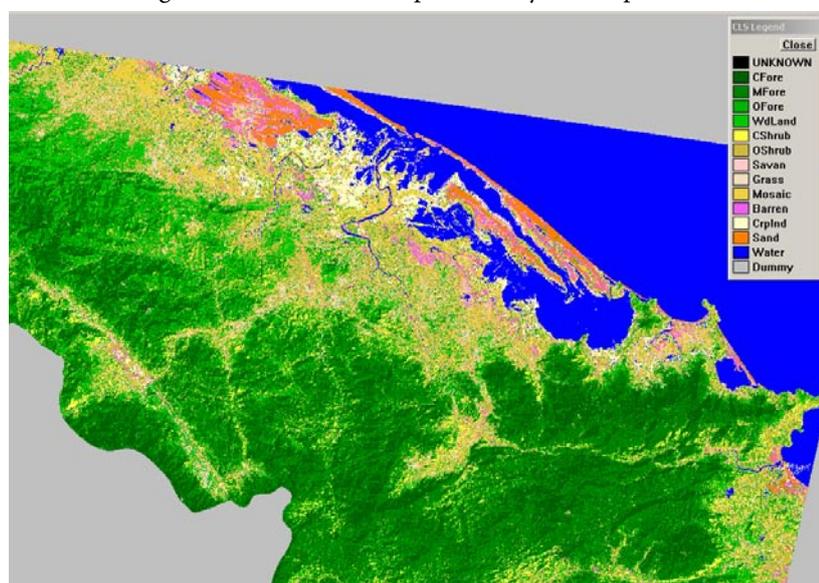
Figure.3: Water Area of the lagoon including flooded area in km<sup>2</sup> of the Tam Giang- Cau Hai lagoon, TT Hue before and after the cyclone hit the coast. (source: IMER - Haiphong, adapted by R.Misdorp)



Remote sensing in combination with mathematical flood modelling of a river basin (Villegas, 2004) is a powerful tool for large range of applications from rescue operations to risk analyse. This Perfume River Basin simulation model predicting the areal extent of flooding, water depth, water volume and especially flood duration, can also be effective in assisting rescue operations, damage assessment and post hazard risk analyses. It may also support integrated spatial planning of the vulnerable low-lying areas in the coastal provinces of Vietnam. The PDF report of Villegas, produced under auspice of the CCP, is available in this CCC-Internet Publication (see CCC V-1-3).

### 5.3 Mapping changes in land use, notably the forest cover in the period 1992 - 2000

Changes in land-use, particularly forest cover were analysed by means of specific techniques of digital image processing using a base map of 1: 100,000 scale. The image of Landsat TM was classified for the lands-use classes: Closed forest, medium forest, open forest, woodland, closed shrub, open shrub, shrub and grassland, grassland, mosaic, bare land, crop land, sand, and water surface (Figure 4). After obtaining two classified images for 1992 and 2000, an analysis of the land-use change was carried out. The preliminary results point to a shift from closed-medium forest to open forest in



the TT Hue mountains. More ground-truthing and field observations are needed to confirm this preliminary result. However, this land-use analysis demonstrates the potential value of remote sensing and GIS application for spatial planning, forest management, assessment of soil stability, river and coastal zone management in TT Hue Province.

Figure 4: Classified Satellite Image displaying land-use patterns of the TT Hue Province and the western part of Da Nang Province, 1<sup>st</sup> January 1992: CFore= Closed Forest; M=medium; O=Open; Wd=Wood. (source: © IMER)

#### 5.4 Estimation of soil erosion related to land-use changes in the TT Hue Province

The combination of Remote Sensing data with Geographic Information Systems (GIS) using Digital Elevation Maps, Soil Maps, Land-use Maps and monthly rainfall and temperature maps, resulted into a rough estimate of soil erosion in the wider TT Hue and Da Nang area. Potential soil erosion estimates for this area were carried out for both 1992 and 2000. The 240 m grid of elevation (DEM) was used to compute the slopes. Rainfall information was obtained from a meteorological station located near to Hue, the capital of TT Hue Province. The potential soil loss was estimated using the Universal Soil Loss Equation (USLE). Two maps of potential soil erosion in 1992 and 2000, with erodibility classification ranging from 5 tons per hectare to larger than 150 tons per hectare/year (see Figure 5), were produced for the wider TT Hue Province and Da Nang area.

Maps of potential soil erosion show that the prominent soil erosion classes in TT Hue and Danang area are: 5-20 ton and 20-50 ton/hectare per year. These figures are only a rough estimate; no comparison was made between these estimated outputs and field observations.

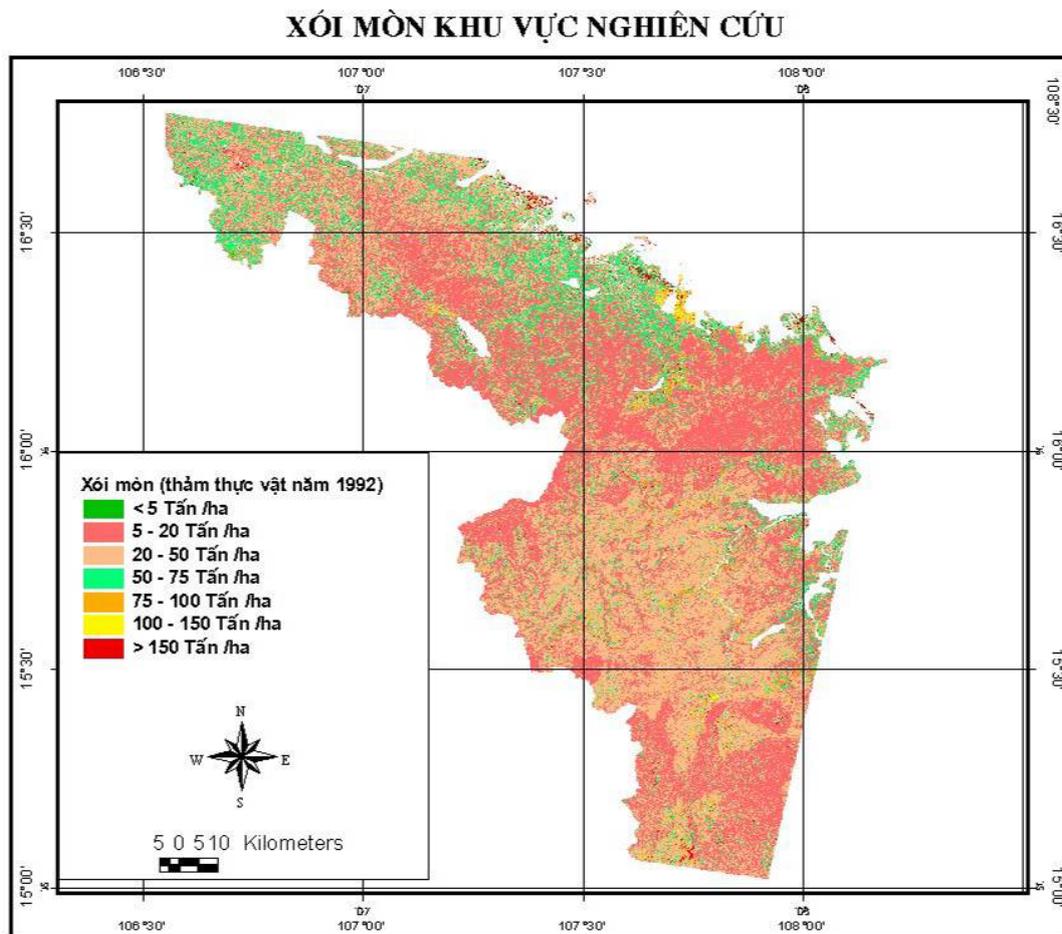


Figure 5: *RS-derived map of potential erosion in 1992 in the area: eastern part of TT Hue Province and western part of Da Nang Province (Tan /ha = ton/ha eroded soil in the year 1992. (source: Institute of Geography)*

The sequential changes in soil erosion estimates can mostly be attributed to land-use changes in the mountains of TT Hue. Analysis of changes in forest cover in 1992-2000 showed a decrease of closed forest by about 10%, which corresponds well with a remotely sensed observed increase in the potential soil erosion during the same period (Tran Dinh Lan, 2003).

The degree of forestry and related soil development in the mountain ranges of the TT Hue Province determines to a large degree the flushing time of the river) and the residence time of the water in the Lagoon, and can provide some order of magnitude estimates of the sedimentation and erosion patterns in the Lagoon and near shore coastal zone.

This information on the changes in land-use in the mountains is useful in establishing datasets for integrated models that quantify water balance, water discharge and sediment transport towards the sea. Changing soil erosion rates are important for water storage, while lagoon sedimentation rates are relevant when estimating the 'life-span' of the lagoon.

### 5.5 Detected changes in shorelines related to coastal hydraulic conditions

Shoreline changes, detected by RS, during the wet season were analysed in the period of 1992-2000. Ground truth data, important for analysis of coastal dynamic processes in TT Hue, were also examined. Sea level, including surges, meteorological data and coastal profiles at and around the time the satellite images were taken, were all used to correct the representation of shoreline change.

The results show that the coastline in two areas of Thuan An and Tu Hien outlets/inlets is highly dynamic (Figure 6). The range of shoreline movement in Thuan An area was 10 – 30 meters landward or seawards, while in Tu Hien area a 15 m landward movement occurred during the 8-year period. Seasonal analysis showed that the oscillation of the shoreline near the outlets could be larger than the averaged 8-year changes.

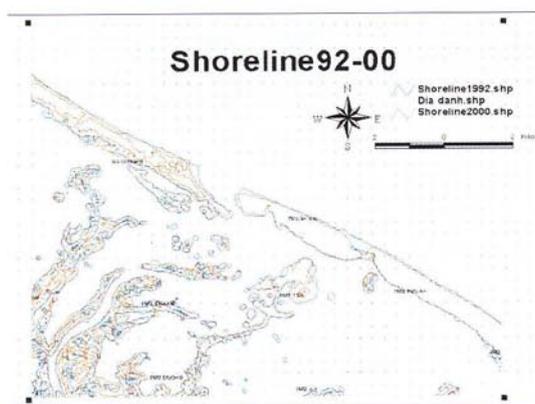
The active coastal beach zone is locally many tens of meters wide – an important consideration when developing guidelines for building (see erosion photo: Figure 7, CC II-8-1) and spatial planning and preparation of buffer zones. Seasonal variations in coastal dynamics are as important as annual changes, and involve high erosion rates during storms/cyclone periods, which are followed by accretion during more quiet periods.



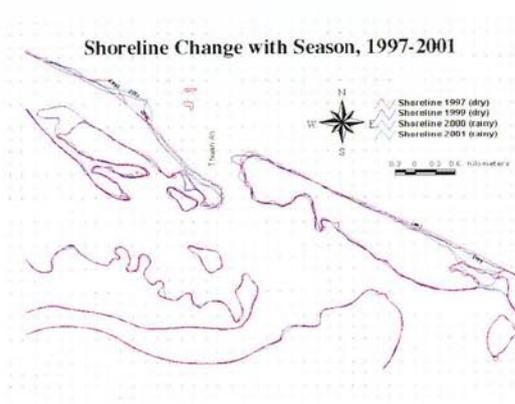
Eroding dune of Thuan An outlet looking from the sea into the Lagoon

Table 2: Flooded areas

| Date 1999 RS images | Water surface In hectares |
|---------------------|---------------------------|
| 01/09: no-flood     | 22,600                    |
| 06/11: flooded      | 63,150                    |
| 10/11:: flooded     | 56,050                    |
| 15/11: flooded      | 41,700                    |



(a)



(b)

Figure 6: Overview of shoreline changes around the outlet of Thuan An, analysed by RS 1992 – 2000: (Shoreline 92-00); strong seasonal shoreline changes in the period 1997 – 2000; the photo shows strong erosion of the coastal dune near the outlet.

**Table with Flooded areas** of the Tam Giang- Cau Hai lagoon water surface area from sequential RS analyses: before, during and after the typhoon of 2- 4<sup>th</sup> of November 1999, see Figure 3. (source: CCP2002; photo: Mindert de Vries)

### 5.6 Changes in aquaculture development in the Tam Giang – Cau Hai lagoon

Aquaculture ponds are clearly visible and easy to be recognised along the borders of the Tam Giang – Cau Hai lagoon using remote sensing images.

The area of aquaculture ponds within lagoon system has strongly increased in recent years. Results obtained from analysis of Landsat images of 1992 and 2001, and ADEOS/AVNIR 1997 provides a preliminary estimate of the aquaculture ponds. The areas of aquaculture ponds estimated by remote sensing are:

- 130 hectare in 1992;
- 430 hectare in 1997;
- 2,200 hectare in 2001;
- 8,200 hectare in 2008 (Nguyen Van Thao, Nguyen Dac Ve, Tran Dinh Lan, Do Thi Thu Huong, Nguyen Thi Thu Ha, 2009)

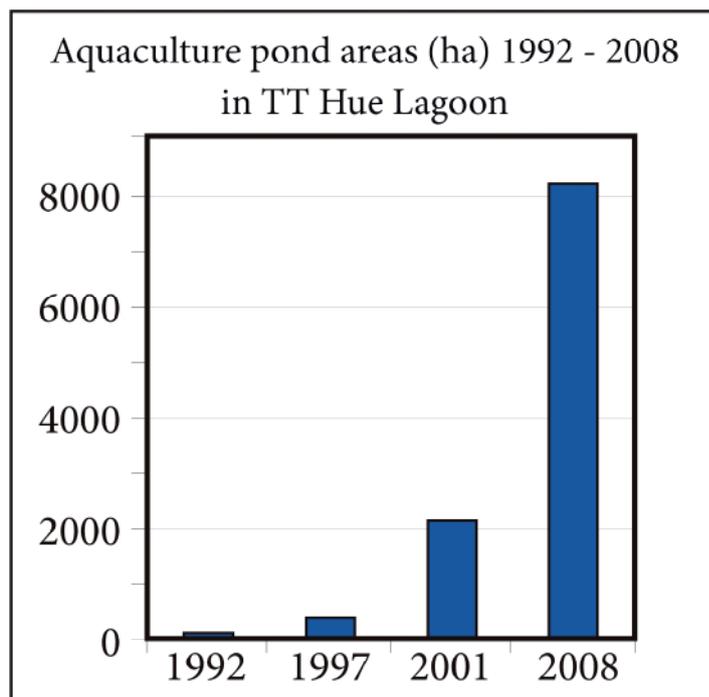
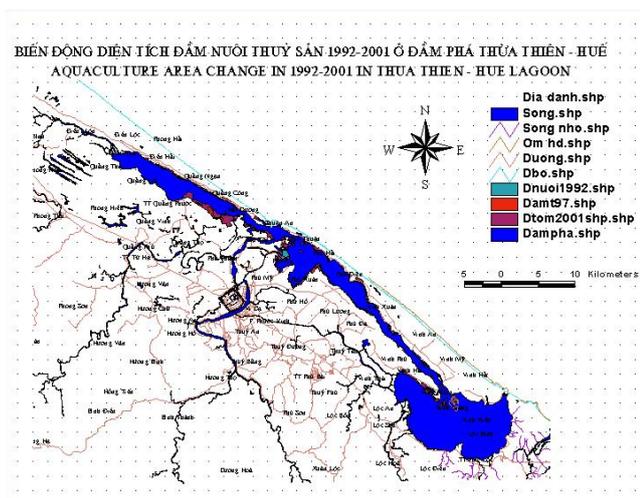


Figure 7: **Strong increase in aquaculture area in the Tam Giang – Cau Hai lagoon**, with the locations of the aquaculture ponds indicated on the map, analysed RS images of 1992, 1997, 2001 and 2008; (sources CCP 2002, adapted)

These data illustrate the enormous areal growth of the aquaculture in the Tam Giang - Cau Hai lagoon system with a factor 16 in 9 years (1997 – 2008). This growth reflects a strong increase of shrimp production and associated economically beneficial export. However, this has been accompanied by a strong increase in the pollutant load in the lagoon.

The detrimental effects of uncontrolled shrimp farming in Thailand is illustrated in CCC II-7-1. A training manual with the Thai lessons learned has also been made available in this CCC Internet Publication , see CCC V-1-1.

Another issue related to fisheries, is the high density of systematically placed “< shaped fishnets” in the entire lagoon system as shown by the high resolution IKONOS “quick look” and even clearly visible on the Google Earth image (see Figure 8) , and demonstrates an extremely intensive lagoon fishery.

This relative cheap and simple remote sensing application constitutes a powerful tool in adjusting fishery practices and enforcing regulations for a more sustainable resource use.

The effects of intense uses of resources are furthermore made “visible” through preliminary integrated coastal modelling, (see paragraph 5.9 and CCC II-8-4). These results were provided to the VN-ICZM program.

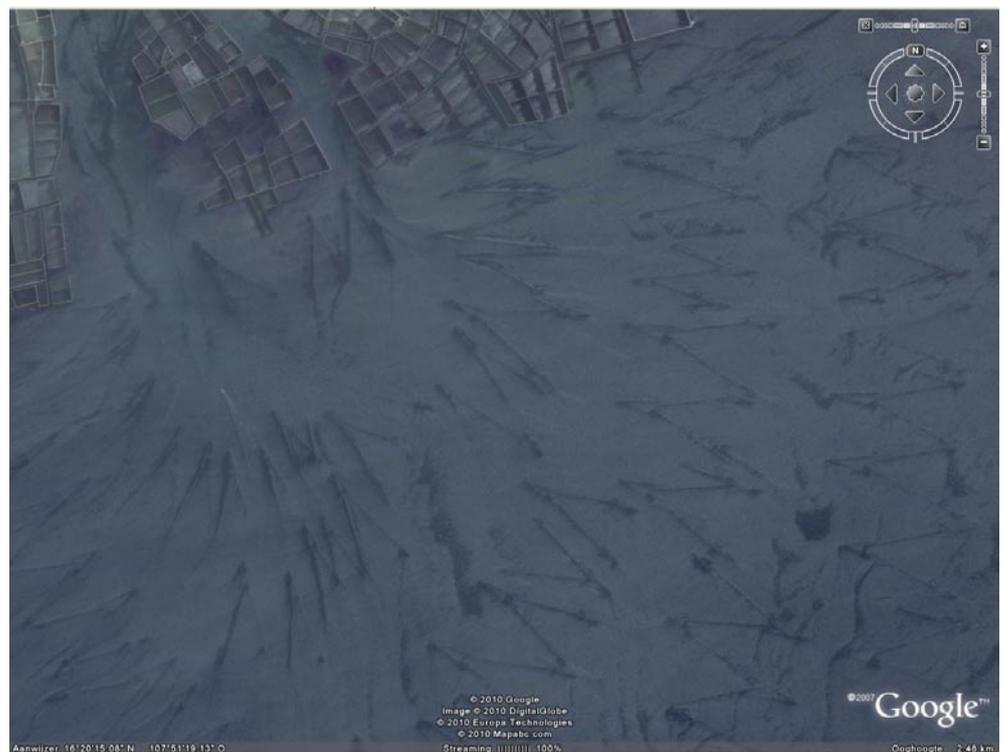
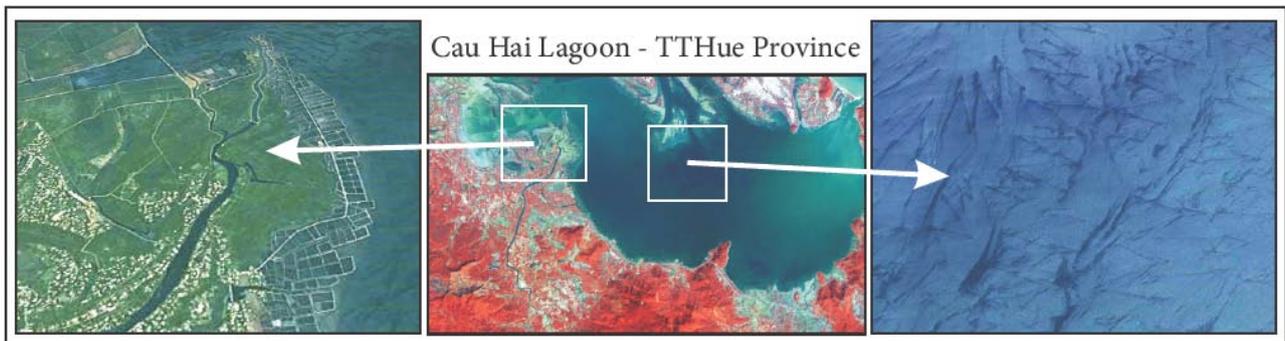


Figure 8a: **Cau Hai Lagoon**, the southern part of the Tam Giang - Cau Hai lagoon system in TT Hue Province with intensive rice cultivation and aquaculture plots (above left), and an abundant number of < shaped fish nets (above right). (source: © IMER).

Fig. 8b: **The occurrence of the abundant V-shaped fishnets in Cau-Hai Lagoon**, on Google Earth images. (photo: Google Earth: ©2010 Google Image ©2010 DigitalGlobe ©2010 Europa Technologies ©2010 Mapabc com)

### 5.7 Meta-database of RS-imageries

An inventory of RS images and remotely sensed data regarding the TT Hue Province was made by the previously mentioned Vietnamese Remote Sensing Centres. This resulted in an overview of 33 useful Remote Sensing images for TT Hue Province. A meta-database was setup and made publicly accessible through the VNICZM project website.

### 5.8 Remote sensing information as input for integrated coastal modelling of the Tam Giang – Cau Hai Lagoon

Preliminary integrated coastal modelling for the TT Hue Province (see CCC II-8-4) focused on the changes in land use and its effects of functional uses (settlements, agriculture and aquaculture) on the functioning of the Lagoon and its ecosystems. This integrated approach revealed the effects of agents of change on the carrying capacity of the lagoon and illuminated the effects of strategies such as zoning of land-uses.

**5.9 Two intensive RS training courses of each two-weeks** were organised in TT Hue Province with the support of a number of Vietnamese and Dutch based institutes in 2002 and 2003. Between 40 – 50 participants/workshop from the TT Hue Province and ITC Alumni were actively contributing

Many results were obtained by the hands-on training in Remote Sensing and GIS activities, revealing the geographical and sequential distribution of natural and socio-economic processes in the coastal zone of TT Hue. These included:

- *A new estimate of soil erosion* for the TT Hue river basins;
- *The strong expansion of aquaculture areas* in the Tam Giang - Cau Hai lagoon;
- *Shoreline changes* along the TT Hue coast and outlets important to defining guidelines for building and spatial planning;
- *Flood sensitivity analysis* showing clearly amongst other things the areas of maximum water depth and the flooding duration;
- *Integrated coastal modelling* incorporating all the results of RS and GIS training exercises, the results of ground truth ecological lagoon survey, the results of analyses on the impacts of socio-economic development and of climate change, resulted in a first attempt of determining the carrying capacity of the Tam Giang – Cau Hai lagoon system now and in the future. The Remote Sensing-GIS derived thematic maps, the RS analysed changes in land-use, the effects on ecosystem surveyed by the CCP lagoon monitoring task force, the river basin model STREAM and the coastal hydraulic conditions, that all were integrated in the coastal modelling

These concrete workshop results served to illustrate the values of Remote Sensing & GIS instruments among the participants and to the high level TT Hue decision makers.

## 6. Conclusions and recommendations

Monitoring natural and socio-economic processes in the coastal zone is required in the various stages of any ICZM programme. Remote sensing is an effective tool to aid coastal zone management and development. It provides spatial and temporal data, improving the knowledge of processes in the coastal zone.

Application of remote sensing for coastal management is a new tool for Vietnam at provincial level. It is especially powerful for making rapid assessments of coastal dynamics, land-use changes, flood mapping and aquaculture development. The data combined with 'ground truthing' are particularly suitable for monitoring, modelling, integrated spatial and temporal analyses and updating of thematic maps. Remotely sensed data support monitoring and assessment of the existing situation, and changes occurring in the coastal zone.

The introduction of new remote sensing instruments in Vietnamese Provinces provides the policy- and decision-making community with tools to:

- 1) Strengthen the provincial capabilities on integrated spatial planning, hazard and risk management, fishery management and aquaculture regulation and enforcement;
- 2) Assess climate change impacts and help prepare appropriate adaptive coastal measures.

Remote Sensing instruments, increasing knowledge on coastal processes, will support more sustainable decision-making, balancing of interests and resolving conflicts of interest,

The two training courses on remote sensing application for coastal management in Thua Thien - Hue Province for about 100 provincial officials and coastal experts, showed how it is possible to develop skills for provincial partners in rapid assessment of coastal matters for management. The TT Hue Province trainees demonstrated the value of the various RS and GIS applications to the high-level provincial authorities.

The exchange between the national Remote Sensing experts of Vietnam as well as the interactions with Dutch experts helped better understanding of the applications and identified new – Remote Sensing - avenues for the province.

Remote Sensing in combination with integrated (river and coastal) modelling is a useful instrument for policy preparation and supports spatial planning particularly in relation to the effects of typhoons as well as the effects of future socio-economic developments and the impacts of climate change on the functioning of the lagoon.

Remote sensing interactions between the international, national and provincial experts and policymakers were shown to be useful for ICZM in the TT Hue Province. This is also illustrated through the RS study of the coastlines in TT Hue Province by Truong Thi Hoa Binh & Tran Minh Y (2008). Furthermore, the experience of the CCP in TT Hue Province were transferred to other Vietnamese Provinces such as Nam Dinh Province, where analysis of remote sensing data was undertaken and initial results were reported (Vietnam National Centre for Science and Technological Information, NCSTI – VISTA).

## 7. References

- **CCP – Vietnam-Netherlands Coastal Cooperative Programme, 2002: Annual Progress report - 2002;** CZM-Centre – CD, January 2003,
- **CCP -Task 5, 2002: Proceedings of Workshop on remote sensing application in ICZM in Thua Thien – Hue Province;** MONRE, Hanoi, 16 September 2002.
- **CCP -Task6-July 2002: Preliminary analyses of meteorological and hydrological data of the TT Hue River Basins;** Laurens Bouwer Institute for Environmental Studies/Free University, The Netherlands & Robbert Misdorp, Coordinator of CCP 2002, CZM-Centre/Min.V&W, The Netherlands.
- **CCP, 2003: Annual Progress report - 2002;** CZM-Centre , CD, The Hague.
- **CCP, 2004: Annual Progress report - 2003;** CZM-Centre, CD, The Hague.
- **Map-Asia Bangkok, 7-9 August 2002: Poster session: “RS/GIS- applications for ICZM in Vietnam province TT Hue.**
- **Misdorp, Robbert ,Hua Chien Thang, Nguyen Xuan Lam, Tran Dinh Lan, Nguyen Manh Cuong, Nguyen Dinh Duong, Tran Huu Tuyen, Mindert de Vries, Tom Bucx, Tjeerd Hobma, 2005: Using Remote Sensing Data for Coastal TT-Hue Province, Vietnam;** International Journal of Geoinformatics, Vol1, No 2, 103-114p, June 2005
- **Nguyen Van Thao, Nguyen Dac Ve, Tran Dinh Lan, Do Thi Thu Huong, Nguyen Thi Thu Ha, 2009: Monitoring and assessment of flooding damages in Thua Thien - Hue coastal area using ALOS satellite images.** Project technical report, Institute of Marine Environment and Resources., Haiphong, Vietnam
- **Tran Dinh Lan, 2003: Results from remotely sensed data analysis for integrated coastal lagoon management in Thua Thien - Hue;** Marine Resources and Environment (Collection of research works), Tom X, Science and Technics Publishing House, Ha Noi, 269-276p.
- **Truong Thi Hoa Binh, Tran Minh Y, 2008: Research the disaster by Remote Sensing and GIS (Case study: Thua Thien - Hue Province , Vietnam;** The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. p 383-384, Beijing 2008

### PDF reports:

- **ADPC (Asian Disaster Preparedness Center), 2003: "Local Institutions Response to 1999 Flood Event in Central Vietnam",** (2003-11-30), Bangkok, Thailand.  
[http://en.wikipedia.org/wiki/1999\\_Pacific\\_typhoon\\_season#Tropical\\_Storm\\_Eve\\_.28Rening.29](http://en.wikipedia.org/wiki/1999_Pacific_typhoon_season#Tropical_Storm_Eve_.28Rening.29)
- **Truong Thi Hoa Binh\*, Tran Minh Y, 2008:**  
[http://www.isprs.org/congresses/beijing2008/proceedings/8\\_pdf/2\\_WG-VIII-2/43.pdf](http://www.isprs.org/congresses/beijing2008/proceedings/8_pdf/2_WG-VIII-2/43.pdf)
- **VNCSTI – Vietnam National Centre for Science and Technological Information:**  
[http://english.vista.gov.vn/english/st\\_documents\\_abstract/200502184030155525/200506035222030440/200506291736409575/200506297155788244/](http://english.vista.gov.vn/english/st_documents_abstract/200502184030155525/200506035222030440/200506291736409575/200506297155788244/)
- **Villegas, Piero, 2004: Flood modelling in Perfume River Basin, Hue Province, Vietnam;** MSc Thesis, ITC (Internat. Inst. for Geo-information Science and Earth Observation), Enschede, the Netherlands.  
[http://www.itc.nl/library/Papers\\_2004/msc/wrem/villegas.PDF](http://www.itc.nl/library/Papers_2004/msc/wrem/villegas.PDF)

### Web sites

- **Deltares – former WL Delft Hydraulics:** Dutch-based research institute and specialist consultancy for matters relating to water, soil and the subsurface:  
<http://www.deltares.nl/en>
- **IMER - Institute of Marine Environment and Resources, Haiphong, Vietnam:**  
[www.imer.ac.vn](http://www.imer.ac.vn)
- **Institute of Geography - Vietnam Academy of Science and Technology:**  
[http://www.vast.ac.vn/en/index.php?option=com\\_content&view=article&id=1013:institute-of-geography-&catid=23:national-institutes&Itemid=103](http://www.vast.ac.vn/en/index.php?option=com_content&view=article&id=1013:institute-of-geography-&catid=23:national-institutes&Itemid=103)
- **ITC – International Institute for Geo-information Science and Earth Observation – the Netherlands:**  
[www.itc.nl/](http://www.itc.nl/) and <http://www.itc.nl/Pub/study/Course-domains/Earth-Sciences>
- **Institute for Environmental Studies, Free University, Amsterdam:**

<http://www.ivm.vu.nl/en/index.asp>

- **GDLA – General Department of Land Administration – Vietnam supported by ITC :**  
<http://itc.eu/Pub/News/in2011/Apr11/Strengthening-Capacity-in-Land-Administration-in-Vietnam.html>
- **Remote Sensing Centre – Ministry of Natural Resources and Environment, Vietnam:**  
<http://rsc.gov.vn/English/index.htm#>